(7)

Vaccinating First-Year College Students Living in Dormitories for Meningococcal Disease

An Economic Analysis

R. Douglas Scott II, PhD, Martin I. Meltzer, PhD, Lonny J. Erickson, MSc, Philippe De Wals, PhD, Nancy E. Rosenstein, MD

Background: Surveillance of meningococcal disease among U.S. college students found an elevated rate of this disease among first-year students living in dormitories.

Objective: This study examines the economics of routinely vaccinating a cohort of 591,587 incoming first-year students who will live in dormitories for ≥1 years.

Methods: A cost–benefit model (societal perspective) was constructed to measure the net present value (NPV) of various vaccination scenarios, as well as the cost/case and cost/death averted. Input values included hospitalization costs from $10,924 to $24,030 per hospitalization; immunization costs (vaccine plus administration costs) from $54 to $88 per vaccine; 30 nonfatal, vaccine-preventable cases over a 4-year period (includes 3 with sequelae); 3 premature deaths; value of human life from $1.2 million to $4.8 million; and long-run sequelae costs from $1298 to $14,600. Sensitivity analyses were also conducted on vaccine efficacy (80% to 90%); discount rate (0% to 5%); and coverage (60% to 100%).

Results: The costs of vaccination outweighed the benefits gained with NPVs ranging from −$11 million to −$49 million. The net cost per case averted ranged from $0.6 million to $1.9 million. The net cost per death averted ranged from $7 million to $20 million. The break-even costs of vaccination (when NPV=$0) at 60% coverage ranged from $23 (90% vaccine efficacy) to $5 (80% efficacy).

Conclusions: The model showed that the vaccination program is not cost-saving. Key variables influencing the results were the low number of vaccine-preventable cases and the high cost of vaccination. However, from the perspective of students and parents, the cost of vaccination might be worth the real or perceived benefit of reducing the risk to an individual student of developing meningococcal disease.

Medical Subject Headings (MeSH): economics, cost–benefit analysis, adolescence, universities, meningococcal infections, meningococcal vaccines (Am J Prev Med 2002;23(2): 98–105)

Introduction

Neisseria meningitidis is the leading cause of bacterial septicemia and meningitis in children and young adults in the United States, with high case fatality and morbidity despite good medical care. Disease rates are highest among infants and are increasing among adolescents and young adults.[1] Of 32 reported outbreaks of meningococcal disease between July 1994 and July 1997, four occurred on college campuses.[2] Two thirds of cases are from meningococcal serogroups C, Y, or W135, for which an effective vaccine for older children and adults is available. In 1995, Jackson et al.[3] evaluated the costs and benefits of a vaccination program for U.S. college students.[3] The authors used rates of disease of people aged 18 to 23 years because rates among college students were unavailable. The estimated cost of this program was $45 million annually. Given the low incidence of disease, the authors felt that a program targeted at higher-risk subgroups of college students might be cost effective.

New data sources allow for refinement of that model to evaluate high-risk groups. In 1998, a new surveillance system was initiated to track the incidence of meningococcal disease among U.S. college students. Data from

From the Division of Healthcare Quality Promotion (Scott), Office of the Director (Meltzer), and Division of Bacterial and Mycotic Diseases (Rosenstein), National Center for Infectious Diseases, Centers for Disease Control and Prevention, Atlanta, Georgia; Montérégie Regional Department of Public Health (Erickson), Longueiul, Quebec, Canada; and Department of Community Health Sciences, University of Sherbrooke (De Wals), Sherbrooke, Quebec, Canada

Address correspondence and reprint requests to: Doug Scott, PhD, CDC, NCID, Div of Healthcare Quality Promotion, 1600 Clifton Road NE, MS E-55, Atlanta, GA 30333. E-mail: Dscott1@cdc.gov.

0749-3797/02/$–see front matter
PII S0749-3797(02)00462-2

Table 1. Valuations of benefits[a] and costs[b] of vaccination: five scenarios

Variable	Scenarios				
	Low	Intermediate	High	Worst	Best
Benefits[a]					
Hospital days per case[c]	7 days (2 ICU)	11 days (3 ICU)	15 days (4 ICU)	7 days (2 ICU)	15 days (4 ICU)
Costs per hospitalization[d]	$10,924	$16,998	$24,030	$10,924	$24,030
Value of life lost[e] and associated discount rate	$1,205,127 (5% SDR[e]) $1,818,762 (3% SDR) $2,940,582 (1% SDR)	$1,205,127 (5% SDR) $1,818,762 (3% SDR) $2,940,582 (1% SDR)	$4,800,000	$1,205,127 (5% SDR) $1,818,762 (3% SDR) $2,940,582 (1% SDR)	$4,800,000
Cost of treating a case of sequelae[f]	$1298	$5708	$14,530	$1298	$14,530
Costs[b]					
Cost of vaccine[g]	$36	$52	$68	$68	$36
Vaccine administration[h]	$18	$18	$20	$20	$18
Treatment of side effects[i]	$3500 per 500,000 doses	$3500 per 500,000 doses	$2454 per case; 1 case per 100,000	$2454 per case; 1 case per 100,000	$3500 per 500,000 doses

[a]Benefits are the savings associated with cases and deaths averted.
[b]Costs are those associated with vaccination.
[c]The low estimate is based on Jackson et al.[3] The high estimate is based on information from the Allegheny County, Pennsylvania, Health Department (J. Fellows, Centers for Disease Control and Prevention, unpublished observations data, 1999). The intermediate estimate is the midpoint between the high and the low estimate.
[d]These estimates are for the costs of acute care only. The estimate used for the low and intermediate scenarios is from Jackson et al.[3] adjusted for inflation to July 1999 prices using the health services component of the Consumer Price Index. The high estimate costs come from the Allegheny County, Pennsylvania Health Department (LJE and PDW, unpublished observations, 1999).
[e]For the low, intermediate, and worst scenarios, a life lost was valued using different age-weighted productivity estimates for the group aged 16 to 19 years under the three different discount rates. All the productivity estimates were derived based on a 1% productivity growth rate,[25] amended and updated to 1998 (Fellows, unpublished observations, 1999). For the high and best scenarios, a life lost was valued at the value of a statistical life.[18–20]
[f]The cost estimates for first/year, acute sequelae treatment costs, and the value of lifetime productivity losses were developed using information from Erickson and De Wals (unpublished observations, 1999). The benefit–cost model, developed by Jackson et al.,[3] did not consider treatment costs for long-term sequelae due to lack of evidence. Evidence from Quebec province shows that 1.5% of victims suffering some type of sequelae had multiple amputations of legs and arms, while another 5% had loss of a single limb or loss of toes or fingers.[21] Another 12% of victims had skin scarring. While it is reasonable to assume that cases of multiple amputations experience either a loss in economic well-being or some loss in lifetime productivity, this analysis uses the following range of estimates due to lack of concrete data: 30% as high, 10% as intermediate, and 0% as low. The productivity/loss figure used to calculate these estimates is $2.94 million (0% discount, 1% productivity growth). Cost information from Allegheny County, Pennsylvania ($15,500 medical cost for amputations and $5,000 for treatment of skin scarring) (LJE and PDW, unpublished observations, 1999) was used to calculate a high, an intermediate, and low long-term sequelae cost estimate as a weighted average, with the weights being the probability of the above outcomes occurring. The calculations follow:

High:

$$[(\$2{,}940{,}582 \times 0.30 \times 0.015) + (\$15{,}500 \times 0.015)] + (\$15{,}500 \times 0.03) + (\$5{,}000 \times 0.12) = \$14{,}530$$

Intermediate:

$$[(\$2{,}940{,}582 \times 0.10 \times 0.015) + (\$15{,}500 \times 0.015)] + (\$15{,}500 \times 0.03) + (\$5{,}000 \times 0.12) = \$5{,}708$$

Low:

$$[(\$2{,}940{,}582 \times 0.0 \times 0.015) + (\$15{,}500 \times 0.015)] + (\$15{,}500 \times 0.03) + (\$5{,}000 \times 0.12) = \$1{,}298$$

There is insufficient information to develop an appropriate estimate of the long-term direct and indirect lifetime medical costs due to disease-related amputations. For the above calculations, these costs are not included.
[g]The estimate used for the low and best scenarios is the wholesale price for a 10-dose vial at $36 per dose.[21] The estimate used for the high and worst scenarios is the wholesale price for a single dose vial at $68 per dose.[21] The estimate used for the intermediate scenario is an average ($52) of the low and high estimates per dose.
[h]The estimate used for the low, intermediate, and worst scenarios is from Jackson et al.[3] adjusted for inflation to July 1999 prices using the health services component of the Consumer Price Index. The estimate used for the high and worst scenarios comes from LJE and PDW (unpublished observations, 1999).
[i]For the low, intermediate, and best scenarios, the number of side effects is based on incidence rates from Yergeau et al.,[26] with one case of anaphylaxis per million doses (2 days hospitalization) and one severe reaction (one medical consultation) per 10,000 doses. Total treatment costs = $7000 per million doses (LJE and PDW, unpublished observations, 1999). The estimate used for the high and worst scenarios is from Jackson et al.,[3] which is based on one severe systemic reaction per 100,000 doses. These treatment costs were adjusted for inflation to July 1999 prices using the health services component of the Consumer Price Index.
ICU, intensive care unit; SDR, social discount rate.

Table 2. Cases of vaccine-preventable disease, premature death, and sequelae without a vaccination program[a]

Outcomes	Year of occurrence 1	2	3	4	Totals
Nonfatal cases[a]	18	4	4	4	30
Premature deaths	2	1	0	0	3
Cases of sequelae[b]	2	1	0	0	3

[a]The number of cases refers to those that occur over a 4-year period in a cohort of first-year students entering college who spend at least their first year in dormitories.
[b]These cases of sequelae are a subset of nonfatal cases. Thus, to avoid double accounting, the cases of sequelae should not be included when adding up the total number of cases (fatal and nonfatal).

this system, along with earlier surveillance data from Maryland,[4,5] indicates that first-year students living in dormitories face a higher risk of meningococcal disease. This study provides a new cost–benefit analysis for routinely vaccinating U.S. first-year college students living in dormitories.

Methods

Economic Analysis

The analysis uses a cohort of 591,587 first-year students[6–8] living in dormitories during the 1998–1999 school year (the only year for which data were available prior to any policy actions). We assumed that the cohort lived in dormitories for at least their first year of college (students often move out of dormitories after the first year). The incidence of disease, premature death, and sequelae occur over 4 years, while vaccination occurs at the beginning of Year 1.

The model used the net present value (NPV) criterion (Appendix A). The benefits of averting disease through vaccination include the treatment-cost savings (hospital expenses associated with acute treatment); averting a premature death (using both lifetime productivity loss and the value of a statistical life); and the cost savings of averting disease-related sequelae. Program costs included costs of vaccine, vaccine administration, and vaccine-related side effects.

Other outcome measures included net cost per case averted, premature death averted, and life-years saved (NPV divided by cases averted, deaths averted, and life-years saved, respectively). For the net-cost calculations incorporating the statistical value of life (Table 1), the numerator retained all dollar valuations of life saved, even if such valuation incorporated intrinsic values already contained in the denominator term "death averted."[9] This biased the analysis toward intervention. These net-cost ratios were not comparable to cost-effectiveness ratios that are derived using lifetime productivity losses.[10] However, net-cost ratios based on lifetime productivity losses were also derived and were comparable to cost-effectiveness ratios from other healthcare interventions.

Table 3. Net present values assuming 60% vaccination coverage (US$ millions)

Program costs (NPV)	Best $19.2	Low $19.2	Intermediate $24.8	High $31.2	Worst $31.2
90% Efficacy					
0% DR	−$11.0	−$14.2	−$19.8	−$23.1	−$26.3
3% DR	−$11.1	−$16.1	−$21.7	−$23.2	−$28.2
5% DR	−$11.1	−$17.1	−$22.7	−$23.2	−$29.2
85% Efficacy					
0% DR	−$11.4	−$14.5	−$20.1	−$23.5	−$26.6
3% DR	−$11.5	−$16.2	−$21.8	−$23.6	−$28.3
5% DR	−$11.6	−$17.2	−$22.8	−$23.6	−$29.3
80% Efficacy					
0% DR	−$11.9	−$14.8	−$20.4	−$24.0	−$26.9
3% DR	−$11.9	−$16.4	−$22.0	−$24.0	−$28.5
5% DR	−$12.0	−$17.3	−$22.9	−$24.1	−$29.4

DR, discount rate; NPV, net present value.

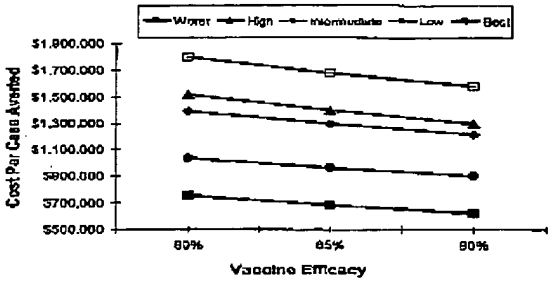

Figure 1. Cost per case of meningococcal disease averted due to vaccinating a cohort of college freshmen initially living in dormitories. See Table 1 for the assumptions regarding the costs and benefits related to each scenario. The number of nonfatal and fatal vaccine-preventable cases of disease used in the analyses are presented in Table 2. The assumed cohort size was 591,587 first-year students entering dormitory life. The results relate to preventing cases of disease over the entire 4 years of the cohort's academic undergraduate experience.

Cost Data

The NPV model was evaluated under five different scenarios: low, intermediate, high, worst, and best (Table 1). Each scenario has a different mix of estimates of benefits (cases and deaths averted) and costs of vaccination. The low scenario combined the smallest estimates of benefits (value of cases and deaths averted) with the lowest cost of vaccination. Similarly, the high scenario used the largest estimates of benefits and costs. The intermediate scenario used estimates of benefits and costs that were midpoints between those used to define the low and high scenarios. The worst scenario was the least advantageous to vaccination and combined the lowest benefits with the highest vaccination costs. The best scenario combined the highest benefits with the lowest vaccination costs. Each scenario was evaluated under three assumptions for vaccine coverage (60%, 80%, and 100%); vaccine efficacy (80%, 85%, and 90%); and discount rate (0%, 3%, and 5%). We evaluated 135 scenarios (5 benefit and cost scenarios × 3 coverage scenarios × 3 vaccine efficacy scenarios × 3 discount rates).

The costs saved from averting disease-related sequelae resulted from first-year treatment (including surgery, skin grafts, and prostheses) and lifetime productivity losses resulting from amputations. Cases of sequelae were treated as a subset of the nonfatal cases and were added to the cost of

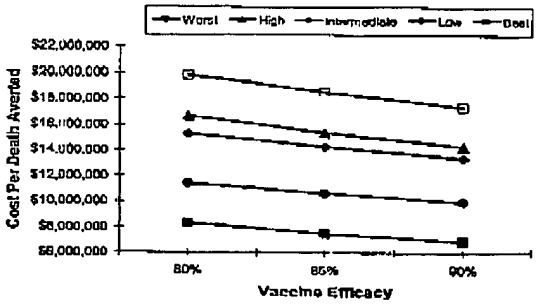

Figure 2. Cost per death averted resulting from meningococcal disease due to vaccinating a cohort of college freshmen initially living in dormitories. See Table 1 for the assumptions regarding the costs and benefits related to each scenario. The numbers of fatal, vaccine-preventable cases of disease used in the analyses are presented in Table 2. The assumed cohort size was 591,587 first-year students entering dormitory life. The results relate to preventing cases of disease over the entire 4 years of the cohort's academic undergraduate experience.

Table 4. Threshold analysis: break-even vaccination costs for 60% vaccine coverage[a]

	Break-even vaccination costs: $ per student vaccinated[a,b]		
	Vaccine efficacy		
Scenario[c]	80%	85%	90%
Worst			
0% DR	12.38	13.15	13.92
3% DR	7.77	8.25	8.69
5% DR	5.25	5.59	5.88
Low			
0% DR	12.38	13.15	13.92
3% DR	7.77	8.25	8.69
5% DR	5.25	5.59	5.88
Intermediate			
0% DR	12.64	13.43	14.22
3% DR	8.02	8.53	8.98
5% DR	5.51	5.86	6.17
High			
0% DR	20.51	21.79	23.07
3% DR	20.35	21.63	22.77
5% DR	20.17	21.48	22.62
Best			
0% DR	20.51	21.79	23.07
3% DR	20.35	21.63	22.77
5% DR	20.17	21.48	22.62

[a]Break-even costs refer to the cost of vaccination (costs of vaccine + costs of administration) required so that, for a given scenario (Table 1), the benefits = the costs (i.e., NPV = $0).
[b]The costs of vaccine administration ranged from $18 (low, intermediate, and best scenarios) to $20 (high and worst scenarios) (Table 1). The costs of vaccine used initially were $36 per dose (low and best scenarios), $54 per dose (intermediate scenario), and $68 per dose (high and worst scenarios) (Table 1). These costs gave a range of costs of vaccination from $54 to $88 per student vaccinated. In addition, costs for treating vaccine-related side effects should be considered (Table 1).
[c]The results shown are applicable to each of the three coverage rate scenarios (see text for further details).
DR, discount rate; NPV, net present value.

hospitalization. Lifetime productivity losses due to multiple amputations were determined by multiplying the number of meningococcal disease-related amputations (assumed to be 1.5% of cases with disease-related sequelae)[11] by the lifetime income loss associated with multiple amputation. Estimating lifetime productivity losses due to amputation was more difficult, given the lack of published evidence and improvements in prosthetic technology. To reflect this uncertainty, three different assumptions for productivity losses (0%, 10%, 30%) were used.

Dividing NPVs by the number of life-years saved, calculated at the corresponding discount rate, yielded the net costs per life-year saved. An estimate of 59.1 years of additional life expectancy for people aged 18 to 19 years[12] was used for this analysis.

Epidemiologic Data

The number of cases and fatalities averted was based on 1 year of surveillance (1998–1999) of U.S. college students.[6–8] Among 591,587 first-year students living in dorms (Year 1), there were 18 vaccine-preventable meningococcal (strains C, Y, and W135) cases (incidence of 3.04 per 100,000) and 2 fatalities (incidence of 0.34 per 100,000) (Table 2). For Years 2 to 4, the incidence of vaccine-preventable disease was 0.67 per 100,000, and the incidence of preventable premature death was 0.17 per 100,000. Assuming the cohort of first-year students remains constant in size and the incidence of cases are distributed equally over time, these rates predict that the cohort would experience an additional four cases per year (for Years 2 to 4) and one death (assigned to Year 2) (Table 2).

Based on a Canadian study[11] and unpublished surveillance data from Allegheny County, Pennsylvania (LJE and PDW, unpublished observations, 1999), the incidence of disease-related sequelae was the same as that of premature death, resulting in two cases of sequelae in Year 1 and one case in Years 2 to 4 (assigned to Year 2) (Table 2).

Vaccine Effectiveness

The only meningococcal vaccine available in the United States is the quadrivalent A, C, Y, W-135 vaccine (Menomune-A,C,Y,W-135, Aventis Pasteur), which consists of four purified bacterial capsular polysaccharides. The range of clinical vaccine efficacies for older children and adults (80% to 90%) was obtained from published literature.[13,14] Clinical efficacies of ≥85% among older children and adults have been shown for the polysaccharide vaccines for serogroups A and C.[15] Although clinical evidence is lacking as to their efficacies, the polysaccharide vaccines for serogroups Y and W-135 can produce bactericidal antibodies.[15] Vaccine effectiveness was assumed to remain constant over the 4 study years, and it is also assumed that vaccination generates no herd immunity. While studies on vaccine effectiveness have tended to show a decline of efficacy through time (particularly for young children),[15,16] evidence from a Canadian meningococcal vaccination campaign showed that vaccine efficacy over 5 years averaged 83% for people aged 15 to 20 years.[17] While assuming constant vaccine efficacy may introduce a slight bias in favor of vaccination, the impact is minor since the majority of predicted cases occur in Year 1.

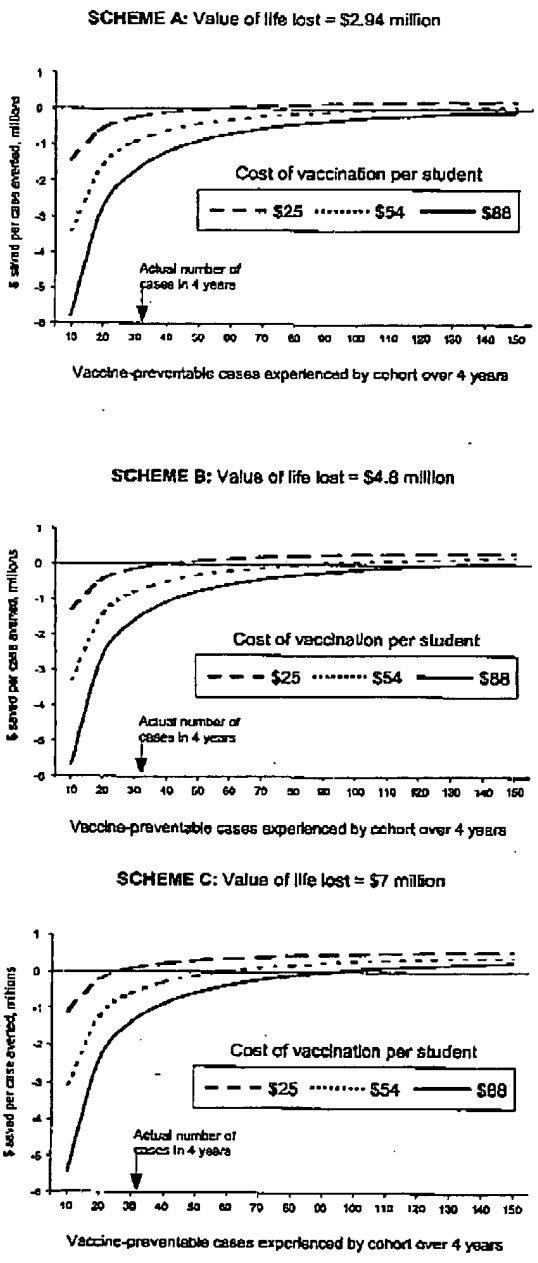

Figure 3. Sensitivity analysis. Impact on savings per case of meningococcal disease averted with changes in number of cases experienced by a cohort over 4 years. This graph documents the effect on savings per case prevented due to variations in the costs of vaccination, the number of vaccine-preventable cases experienced by a cohort of college freshmen living in dormitories over a 4-year period, and the value placed on human life. The y-axis measures the dollars saved per case of meningococcal disease prevented. A negative value indicates a net cost per case averted. For Scheme A, the underlying assumptions are as follows: 80% vaccination coverage; 85% vaccine efficacy; a lifetime productivity measure of $2.94 million (discounted at 1% assuming a 1% productivity growth rate) for the value of life; hospital costs of $24,030 per case; treatment of vaccine side effects of $2454 per case (four cases total); and costs of treating disease sequelae at $14,600 per case. For Scheme B and Scheme C, underlying assumptions are the same as Scheme A except that a value of life of $4.8 million and $7.0 million, respectively, were used. The three cost-of-vaccination scenarios ($25, $54, and $88) include both the price of the vaccine ($7, $36, and $68, respectively) and a vaccine administration fee ($18, $18, and $20, respectively). Total cost of vaccination was calculated for a cohort of 591,587 first-year students entering dormitory life.

Sensitivity Analyses

Threshold analyses were conducted to determine the break-even cost of vaccination (cost of vaccine + costs of administration) for each of the 135 scenarios. Break-even cost is the cost of vaccination needed so that the sum of the benefits equals the sum of the costs (i.e., NPV=$0).

Sensitivity analyses were conducted by varying the number of vaccine-preventable cases from 10 to 150. The unit of outcome for these analyses was costs per case averted. For each assumed number of cases, the proportion of deaths and cases of sequelae are the same as in the surveillance data (Table 2). Three pricing schemes (A, B, and C) for the value of a human life were used, with each scheme having three different vaccination costs. For scheme A, the lifetime productivity loss of a premature death equaling $2.94 million (Table 1) was used; for scheme B, a value of statistical life equaling $4.8 million[18–20] (Table 1) was used. For scheme C, the value of statistical life was placed at $7 million (the highest value of statistical life estimate suggested by the literature).[18–20] Three vaccination costs were used in each scheme: $25, $54, and $88 per student. These costs included both the vaccine price ($7, $36, and $68, respectively)[21] and the administration fee ($18, $18, and $20, respectively). For all schemes, we assumed 80% vaccination coverage, 85% vaccine efficacy, hospitalization costs of $24,030 per nonfatal case, vaccine-related side effects costs of $2454 per case (four cases total), and disease-related sequelae costs of $14,600 per case (Table 1).

Results

Outcome Measures

Regardless of program-cost scenarios, the social costs of the vaccination program outweighed the benefits gained. NPVs were always negative (range, −$11 million to −$49 million), and reducing vaccine efficacy resulted in greater negative NPVs. Discounting had little effect on the magnitude of the NPVs calculated because all program costs, and most program benefits, occurred in the first year and were not subject to discounting. Assuming 60% coverage, negative NPVs ranged from −$11 million (at 0% discount rate and 90% vaccine efficacy) to −$29.4 million (at 5% discount rate and 80% vaccine efficacy) (Table 3). For 80% and 100% coverage, NPV ranged from −$14.8 million to −$39.2 million and −$18.3 million to −$49 million, respectively (data not shown).

The net cost per case averted for each scenario, assuming three different discount rates and three vaccine efficacies for 60% vaccine coverage, are presented in Figure 1. The maximum net cost per case averted was $1.85 million (assuming 80% vaccine efficacy and 5% discount rate) for the worst scenario (Figure 1). The minimum cost per case averted was $617,000 (assuming 90% vaccine efficacy and 0% discount rate) under the best scenario (Figure 1). Altering vaccine coverage from 60% to either 80% or 100% did not notably change the results (data not shown).

For any given scenario (Table 1), the net cost per death averted was approximately ten times greater than the net cost per case averted (Figures 1 and 2). Otherwise, the patterns of net cost per death averted were similar to those for net cost per case averted. The highest net cost per death averted occurred under the worst scenario, ranging from approximately $16.2 million (90% vaccine efficacy, 0% discount rate) to $20.4 million (80% vaccine efficacy, 5% discount rate). The lowest net cost per death averted (under the best scenario) ranged from $6.8 million to $8.3 million for vaccine efficacies and discount rates of 90% and 0%, and 80% and 5%, respectively (Figure 2).

The undiscounted number of life-years saved due to vaccination was 177.3 years (3 lives saved × 59.1). At a 3% discount rate, the number of life-years saved is 85.9, while at 5%, the number is 60.1. Assuming 60% coverage, net costs per life-year saved range from $62,042 (90% efficacy, 0% discount rate) under the best scenario to $489,185 (80% efficacy, 5% discount rate) under the worst scenario.

Sensitivity Analyses

The results of the threshold analyses are shown in Table 4. For each given scenario and assumed vaccine efficacy, the break-even cost of vaccination was the same regardless of vaccine coverage level (coverage appears in both the numerator, the benefits of vaccination, and the denominator, the number of students vaccinated). Thus, for brevity, the results are presented for 60% coverage only. The break-even cost of vaccination ranged from $23.07 for the best scenario (vaccine efficacy of 90%, discount rate 0%) to $5.25 for the worst scenario (vaccine efficacy of 80%, discount rate of 5%) (Table 4). At the lower vaccine-administration fee of $18, the price of the vaccine would need to be ≤$5.00 to produce a positive net social benefit under the best scenario. For the worst scenario, the costs of administrating the vaccine are not even covered, so there would not be a positive net social benefit even if the vaccine were free.

The impact of variations in the number of vaccine-preventable cases on dollars saved per case averted cases is shown in Figure 3. The lower the vaccination costs and the greater the number of vaccine-preventable cases, the closer vaccination comes to a positive dollars saved per case averted. In scheme A, only by assuming a vaccination cost of $25 per student (less than half of the lowest cost used in the initial set of scenarios) does the break-even threshold occur, at approximately 60 cases over 4 years (Figure 3). This break-even number of cases is approximately double the number actually experienced (Table 2). Assuming a vaccination cost of $54 per student, even at 100 cases over 4 years, the net cost per case averted is $85,000 (i.e., negative savings per case averted) (Figure 3).

For the remaining schemes, at vaccination costs of $25, $54, and $88 per student, the break-even point occurred in scheme B at approximately 40, 85, and 135 cases, respectively, over 4 years, and in scheme C at approximately 30, 60, and 90 cases.

Discussion

This analysis consistently demonstrates that a publicly funded program to vaccinate first-year students living in dormitories against meningococcal disease will result in a net economic loss to society (Figures 1 and 2), even under wide variations of vaccination costs and benefits. This finding is similar to previous findings.[3] Using the net cost per life-year–saved ratios (ranging from $0.8 to $1.5 million) based on indirect lifetime productivity costs (the low, intermediate, and high scenarios), the vaccination program compares favorably to other life-saving health interventions. Life-saving health interventions such as annual cervical cancer screening for women beginning at 20 years of age (as opposed to screening every 2 years) and certain select cholesterol treatment programs cost over $1 million per life-year saved (based on 1993 dollars).[22] However, many childhood immunization programs (e.g., polio, rubella, and measles–mumps–rubella vaccinations) result in a cost savings per life-year saved.[22]

The smallest estimated net cost per death averted was approximately $6.8 million (Figure 2). This cost is in addition to the $4.8-million valuation of a life lost, which is already included in the calculation (best scenario in Table 1). Sensitivity analysis also shows that even at a vaccine price of $25, the break-even number of disease cases is 40 (assuming $4.8 million per life lost) and 60 ($2.94 million per life lost). Only when the value per life lost is $7 million and vaccination costs are $25, does the break-even number of cases fall below the 33 cases predicted (to approximately 28 cases).

The model results were only part of the evidence considered when the Advisory Committee on Immunization Practices (ACIP) revised recommendations for vaccination of college students. While the ACIP did not recommend routine vaccination for this subgroup of college students,[23] both the ACIP and the American Academy of Pediatrics[24] recommend that students and parents be advised of the elevated risk for meningococ-

cal disease and the benefits of immunization for first-year students living in dorms.

Limitations of our model include a lack of information on program implementation and compliance costs. Also, by assuming no dropouts in the cohort over time, the estimated number of cases available to be averted over 4 years (Table 2) may be greater than actually experienced. While missing administrative costs result in understating program costs and assuming no dropouts results in overstating disease costs averted, their relative contribution to total costs is minor and should not affect the results.

Economic benefits that were not considered include (1) the cost savings of avoiding antimicrobial chemoprophylaxis, vaccinating large numbers of the university population during an outbreak, or both; (2) the long-term direct and indirect medical costs of prostheses replacement, readaptation treatment, wheelchairs, home adaptations, counseling for cases with amputation, and other possible indirect costs on families; and (3) the intangible benefits of reduced fear and stress in a university community due to a severe case of meningococcal disease. However, the relatively low costs of antimicrobial prophylaxis,[23] the low number of serogroup C meningococcal outbreaks (only one per year),[2,4] and the low incidence of long-term sequelae do not produce cost savings significant enough to affect the results. A severe case can increase fear and anxiety within the community and result in negative publicity for the affected institution. If incidence of disease increases, these impacts might become significant.

Conclusion

Even under the most optimistic cost–benefit scenarios, routinely vaccinating U.S. first-year college students living in dormitories results in substantial social costs that exceed the potential social benefits of averted disease. Given the low incidence of disease and the high cost of a vaccination program (see Appendix B for the relative importance of input variables), scarce public health resources could be targeted to more common health conditions. However, because meningococcal disease can have very dramatic health consequences, students or their parents or both may wish to pay for a vaccination in order to reduce the risk of morbidity and mortality from meningococcal disease. While the ACIP did not make a recommendation for routine vaccination, it did suggest that physicians and colleges provide more information about meningococcal disease and the vaccine to entering students, especially those who will live in dormitories, and their parents so that they can make educated decisions regarding meningococcal vaccination.

We are grateful to Kathleen Shutt, Michael Bruce, and Jennifer Caperella for their assistance in obtaining data on meningococcal disease, and to Brad Perkins, David Fleming, Georges Peter, and J Shaw for suggestions and additional input.

References

1. Rosenstein NE, Perkins BA, Stephens DS, et al. The changing epidemiology of meningococcal disease in the United States, 1992–1996. J Infect Dis 1999;1894–901.
2. Woods CR, Rosenstein N, Perkins BA. Neisseria meningitidis outbreaks in the United States, 1994–97. In: Abstracts of the 38th Annual Meeting of the Infectious Disease Society of America. Denver, CO: November 12–15, 1998:125FR.
3. Jackson LA, Schuchat A, Gorsky RD, Wenger JD. Should college students be vaccinated against meningococcal disease? A cost–benefit analysis. Am J Pub Health 1995;85:848–5.
4. Broesche J. Meningococcal disease in college students. Clin Infect Dis 1999;29:215–6.
5. Harrison LH, Dwyer DM, Maples CT, et al. Risk of meningococcal infection in college students. JAMA 1999;281:1906–10.
6. Bruce M, Rosenstein NE, Caparella J, Perkins BA, Collins MJ. Meningococcal disease in college students. Abstracts of the 39th Annual Meeting of Infectious Disease Society of America. Philadelphia, PA: November 18–21, 1999:63.
7. Bruce MG, Rosenstein NE, Caparella JM, Shutt KA, Perkins BA, Collins MJ. Risk factors for meningococcal disease in college students. JAMA 2001;286: 688–93.
8. U.S. Department of Education, National Center for Education Statistics. Digest of education statistics, 1998. Washington, DC: National Center for Education Statistics, 1999.
9. Gold MR, Siegel JE, Russell LB, Weinstein MC, eds. Cost-effectiveness in health and medicine. New York: Oxford University Press, 1996.
10. Kuchler F, Golan E. Assigning values to life: comparing methods for valuing health risks. Washington, DC: U.S. Department of Agriculture, Economic Research Service, Food and Rural Economics Division, 1999 (Agricultural Economic report no. 784).
11. Erickson L, De Wals P. Complications and sequelae of meningococcal disease in Quebec, Canada, 1990–1994. Clin Infect Dis 1998;26:1159–64.
12. U.S. Census Bureau. Statistical abstract of the United States, 1999. Vital Statistics. Washington, DC: Government Printing Office, 1999.
13. Rosenstein NE, Levine O, Taylor J, et al. Efficacy of meningococcal vaccine and barriers to vaccination. JAMA 1998;279:435–9.
14. Griffs JM, Brandt BL, Braund DD. Human immune response to various doses of group V and W135 meningococcal polysaccharide vaccines. Infect Immun 1982;37:205–8.
15. Zangwill KM. Duration of antibody response after meningococcal polysaccharide vaccination in US Air Force personnel. J Infect Dis 1994;169:847–52.
16. Reingold AL. Age-specific differences in duration of clinical protection after vaccination with meningococcal polysaccharide A vaccine. Lancet 1985;2:114–8.
17. De Wals P, De Serres G, Niyonsenga T. Effectiveness of a mass immunization campaign against serogroup C meningococcal disease in Quebec. JAMA 2001;285:177–81.
18. Viscusi WK. The value of risks to life and health. J Econ Lit 1993;31:1912–46.
19. U.S. Environmental Protection Agency, Office of Air and Radiation. The benefits and costs of the Clean Air Act, 1970 to 1990. Report prepared for the U.S. Congress. Washington, DC: U.S. Environmental Protection Agency, 1997.
20. Crutchfield S, Buzby JC, Roberts T, Ollinger M, Lin JCT. An economic assessment of food safety regulations: the new approach to meat and poultry inspection. . Washington, DC: U.S. Department of Agriculture, Economic Research Service, 1997 (Agricultural Economic report no. 755).
21. Medical Economics Company. 1999 Drug topics red book. Montvale, NJ: Medical Economics Company, 1999.
22. Tengs TO, Adams ME, Pliskin JS, et al. Five hundred life-saving interventions and their cost-effectiveness. Risk Analysis 1995;15:369–90.
23. Centers for Disease Control and Prevention. Prevention and control of meningococcal disease and Meningococcal disease and college students—recommendations of the Advisory Committee on Immunization Practices (ACIP). MMWR Morb Mortal Wkly Rep 2000;49:1–22.
24. American Academy of Pediatrics, Committee on Infectious Diseases. Meningococcal disease prevention and control strategies for practice-based physicians (addendum: recommendations for college students). Pediatrics 2000;106:1500–4.

25. Haddix AC, Teutsch SM, Shaffer PA, Dunet DO, eds. Prevention effectiveness: a guide to decision making and economic evaluation. New York: Oxford University Press, 1996.
26. Yergeau A, Alain L, Pless R, Yves R. Adverse events temporally associated with meningococcal vaccines. Can Med Assoc J 1996;154:503–7.

Appendix A
Calculation of Net Present Value

The analysis attempts to take the societal perspective where all benefits and costs associated with a vaccination program for first-year college students are counted. The model used to calculate NPVs of such a program is defined as

$$NPV = \sum_{t=1}^{t=4} (\text{Benefits} - \text{Costs})/(1 + r)^t$$

where:

Benefits = costs of treatment of disease saved + value of premature death saved + costs of treatment of disease-related sequelae saved + value of disease-related sequelae,

Costs = cost of vaccine + vaccine administration costs + treatment of vaccine-related side effects

t = time period (Years 1 to 4 after immunization), and

r = discount rate (evaluated at 0%, 3%, and 5%).

Appendix B
Relative Importance of Input Variables

By considering the impact on NPVs from changes in each input variable (see Figures 1 to 3), the total number of cases appears to be the most important variable influencing the results (Table B1).[1] The data in Figure 3 support this conclusion. When the number of cases increased from 10 to 30 per 4-year period, the net costs per case averted decreased by 80%. The second most important variable is the cost of vaccination. When the cost of vaccination decreased by 40% (from $54 to $88 per student), the cost per case averted decreased by 42% (Figure 3). As seen in Figures 1 and 2, increases in vaccine efficacy cause an almost proportionate decrease in cost per case averted or death averted. Thus, vaccine efficacy is the third most important variable in the models. Increasing the value of a life lost from $2.94 million (1% discounted lifetime productivity measure) to $7 million (a 138% increase) decreased the cost per case averted by only 6.3% (assuming 10 cases per 4 years, $88 per vaccination; see Figure 3). Figures 1 and 2 also clearly demonstrate that vaccine coverage does not have an impact on the model results in terms of costs per case, or death, averted.

Table B1. Relative importance[a] of input variables in determining the cost-effectiveness of routinely vaccinating freshmen college students against meningococcal disease

Relative importance[a]	Variable
1 (Most influential)	Total number of cases[b]
2	Cost of vaccination per student[c]
3	Vaccine efficacy[d]
4	Value of life lost[e]
5	Discount rate[f]
5 (Least influential)	Vaccine coverage[g]

[a]Relative importance was determined by considering the magnitude of changes in an outcome measure (e.g., net present values and cost per case averted) with changes in the five listed inputs. The results used to evaluate relative importance are presented in Figures 1 to 3 and in the text (Results section).
[b]Includes deaths and nonfatal cases that result in long-term sequelae (Table 2).
[c]Cost of vaccination is the sum of the cost per dose of vaccine + the cost of administration. In addition, vaccination will result in some costs associated with vaccine-related side effects (Table 1).
[d]Three scenarios of vaccine efficacy were used: 80%, 85%, and 90%.
[e]Value of life lost was set at either the lifetime productivity measure ($2.94 million, $1.81 million, or $1.21 million) for the three discount rates used or the value of a statistical life ($4.8 million and $7.0 million). See Table 1 and text for further explanation.
[f]The three discount rates used were 0%, 3%, and 5%.
[g]Three scenarios of vaccine coverage were used: 100%, 80%, and 60%.